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Letter

Search for supersymmetric particles in events with lepton pairs and large missing transverse momentum in $\sqrt{s} = 7$ TeV proton–proton collisions with the ATLAS experiment

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Abstract Results are presented of searches for the production of supersymmetric particles decaying into final states with missing transverse momentum and exactly two isolated leptons in $\sqrt{s} = 7$ TeV proton–proton collisions at the Large Hadron Collider. Search strategies requiring lepton pairs with identical-sign or opposite-sign electric charges are described. In a data sample corresponding to an integrated luminosity of 35 pb^{-1} collected with the ATLAS detector, no significant excesses are observed. Based on specific benchmark models, limits are placed on the squark mass between 450 and 690 GeV for squarks approximately degenerate in mass with gluinos, depending on the supersymmetric mass hierarchy considered.

Many extensions of the Standard Model (SM) predict the existence of new states decaying to invisible particles, often motivated by dark matter arguments. If such states are produced in collisions at the Large Hadron Collider, then they can potentially be identified by the presence of missing transverse momentum generated by the invisible decay products. The most important SM backgrounds, in particular jets from QCD production processes (referred to as "QCD jets" hereafter), can be suppressed by requiring in addition the presence of leptons in the final state. Particles predicted by supersymmetric (SUSY) theories [1–9] can be sought with such a signature, with the missing transverse momentum generated by the production of weakly interacting lightest supersymmetric particles (LSP), and the leptons produced in the cascade decay of supersymmetric particles.

In this letter the first results of searches for the production of SUSY particles at ATLAS using final states with two leptons and missing transverse momentum are presented. Leptons are produced through the decays of charginos and neutralinos into W and Z bosons, and into real or virtual sleptons, the SUSY partners of leptons, if their masses are light enough. The main sources of leptons in SM events include W and Z decays, fake leptons from misidentification of jets and non-isolated leptons from heavy flavour decays. Two search strategies are described which require, respectively, isolated leptons of same-sign (SS) or opposite-sign (OS) electrical charge. SS lepton production in SM events is rare. On the other hand, the production of gluinos, which decay with the same probability to squark+anti-quark and anti-squark+quark pairs, and of squark-squark pairs, provides an abundant source of SS lepton pairs in SUSY events [10, 11]. When imposing the OS lepton pair requirement the SM background is larger. However, the signal cross section is also increased by the additional production of squark+anti-squark pairs. The results reported here are complementary to those from SUSY searches requiring lepton pairs of identical flavour [12], and also those from inclusive searches requiring jets, missing transverse momentum and zero leptons [13] or one lepton [14]. A search by CMS for SUSY in events with OS lepton pairs is reported in Ref. [15].

The ATLAS detector [16] is a multipurpose particle physics apparatus with a forward–backward symmetric cylindrical geometry and near 4π coverage in solid angle.[1] The inner tracking detector (ID) consists of a silicon pixel detector, a silicon microstrip detector (SCT), and a transition radiation tracker (TRT). The ID is surrounded by a thin superconducting solenoid providing a 2 T magnetic field, and by high-granularity liquid-argon (LAr) sampling

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[1] ATLAS uses a right-handed coordinate system with its origin at the nominal interaction point (IP) in the centre of the detector and the z-axis coinciding with the axis of the beam pipe. The x-axis points from the IP to the centre of the LHC ring, and the y axis points upward. Cylindrical coordinates (r, ϕ) are used in the transverse plane, ϕ being the azimuthal angle around the beam pipe. The pseudorapidity is defined in terms of the polar angle θ as $\eta = -\ln\tan(\theta/2)$.

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electromagnetic calorimeters. A hadron calorimeter of iron-scintillator tiles provides coverage in the central rapidity range. The end-cap and forward regions are instrumented with LAr calorimetry for both electromagnetic and hadronic measurements. The muon spectrometer (MS) surrounds the calorimeters and consists of three large superconducting toroids, a system of precision tracking chambers, and detectors for triggering.

The full 2010 ATLAS pp dataset is used in this analysis, collected at the LHC at a centre-of-mass energy of 7 TeV. Application of basic beam, detector and data-quality requirements results in a dataset corresponding to a total integrated luminosity of 35 pb^{-1}. The uncertainty on the integrated luminosity is estimated to be 11% [17]. The data have been collected with a single lepton (e or μ) trigger. The detailed trigger requirements vary throughout the data-taking period owing to the rapidly increasing LHC luminosity and the commissioning of the trigger system. The requirements are such that the trigger efficiency is constant and stable for leptons with transverse momentum $p_{\mathrm{T}} > 20$ GeV. The efficiency of the triggers has been studied using data, and agrees well with expectations.

Monte Carlo (MC) event samples are used to develop and validate the analysis procedure, determine detector acceptance and reconstruction efficiency, and transfer background expectations from control regions to signal regions. These samples are also used to model the sub-dominant SM backgrounds. Samples of QCD jet events are produced with the PYTHIA generator [18]. Production of top quark pairs and single top is simulated with the MC@NLO generator [19–21], with an assumed top-quark mass of 172.5 GeV. Samples of W and Z/γ^* production with accompanying jets are produced with the ALPGEN generator [22] for $m_{\ell\ell} > 40$ GeV. Low mass dileptons from Z/γ^* production are generated with PYTHIA. Di-boson (WW, WZ, ZZ) production is simulated with the HERWIG generator [23, 24]. All the MC samples are normalised to the available next-to-next-to-leading order (NNLO) or next-to-leading order (NLO) QCD calculations, except the QCD jet sample, which is normalised to the leading order PYTHIA cross section. Fragmentation and hadronisation for the ALPGEN and MC@NLO samples is performed with HERWIG, using JIMMY [25] for the underlying event model. The MC samples are produced using the ATLAS detector simulation software [26] based on GEANT4 [27]. The MC samples are tuned to reproduce the same average number of primary vertices as in the data in order to take into account multiple inelastic interactions in the same beam crossing.

Criteria for electron and muon identification closely follow those described in Ref. [28]. Electrons in the signal region are required to pass the "tight" selection criteria, have $p_{\mathrm{T}} > 20$ GeV and $|\eta| < 2.47$. Events are removed if an electron satisfying the "medium" selection is found in the transition region between the barrel and end-cap electromagnetic calorimeter, $1.37 < |\eta| < 1.52$. The medium criteria are mainly based on lateral shower shape requirements in the calorimeter and E/p (where E is the shower energy in the calorimeter and p the track momentum in the ID). For the "tight" electron selection, TRT cuts are also applied, which provides additional rejection against conversions and fakes from hadrons. Muons are identified based on matching track segments in both the muon system and the inner detector. For combined muons, a good match between ID and MS tracks is required, and the p_{T} values measured by these two systems must be compatible within the resolution. The summed p_{T} of other ID tracks with $p_{\mathrm{T}} > 500$ MeV within a distance $\Delta R = \sqrt{(\Delta\eta)^2 + (\Delta\phi)^2} < 0.2$ around the muon track is required to be less than 1.8 GeV. Only muons with $p_{\mathrm{T}} > 20$ GeV and $|\eta| < 2.4$ are considered. For the final selection, the distance between the z coordinate of the primary vertex and that of the extrapolated muon track at the point of closest approach to the primary vertex must be less than 10 mm. The electron reconstruction efficiency for medium and tight criteria after the fiducial cuts are about 94% and 75%, respectively. The muon reconstruction efficiency for the combined muons is about 93%.

Jets are reconstructed using the anti-k_T jet clustering algorithm [29] with a distance parameter $R = 0.4$. They are corrected for calorimeter non-compensation, upstream material and other effects using p_{T} and η dependent calibration factors obtained from Monte Carlo and validated with extensive test-beam and collision-data studies [30, 31]. Only jets with $p_{\mathrm{T}} > 20$ GeV and $|\eta| < 2.5$ are considered. If a jet and a selected electron overlap within a distance $\Delta R < 0.2$, the jet is discarded. Furthermore, identified medium electrons or muons are considered only if they satisfy $\Delta R > 0.4$ with respect to the closest remaining jet. Events are discarded if they contain any jet failing basic quality selection criteria that reject detector noise and non-collision backgrounds [32]. The calculation of missing transverse momentum ($E_{\mathrm{T}}^{\mathrm{miss}}$) is based on the modulus of the vector sum of the transverse momenta of the reconstructed objects (jets with $p_{\mathrm{T}} > 20$ GeV over the full calorimeter coverage $|\eta| < 4.9$ and selected leptons), together with any additional non-isolated muons and calorimeter clusters not belonging to reconstructed objects.

Events failing the requirement of at least one reconstructed primary vertex with at least five associated tracks are rejected. Selected events must contain exactly two leptons (e or μ) after the object selection described above. For electrons an isolation criterion is required: the summed calorimeter transverse energy within a distance $\Delta R < 0.2$ around the electron divided by the p_{T} of the electron must be smaller than 0.15. The invariant mass ($m_{\ell\ell}$) of the lepton pair must be greater than 5 GeV. The signal region for OS (SS) events is defined by the requirement $E_{\mathrm{T}}^{\mathrm{miss}} > 150$ GeV

(100 GeV), which was chosen through optimisation of the expected signal significance for a selection of models drawn from the Minimal Supersymmetric Model (MSSM) framework in a mass range just above the existing limits from direct searches.

The main background for the SS analysis arises from SM processes generating events containing at least one fake or non-isolated lepton. These processes are collectively referred to as "fake lepton" background, and mainly consist of $t\bar{t}$, single-top, W+jets and QCD light and heavy flavour jet production. The other significant backgrounds arise from di-boson production and from charge mis-measurements of electrons in $t\bar{t}$ events that have undergone hard bremsstrahlung with subsequent photon conversions. The other SM backgrounds, such as Z boson production, are small, since their contribution is largely suppressed by the $E_{\mathrm{T}}^{\mathrm{miss}}$ cut. For the OS analysis the dominant background arises from $t\bar{t}$ production. In addition, there are contributions from fake or non-isolated leptons, Z+jet, di-boson and single-top production.

For the "fake lepton" background, the origin of the detected leptons are either jets faking leptons or heavy flavoured meson decays into non-isolated leptons. The contribution from this background is estimated from the data using a method that is similar to that described in Ref. [33]. This method defines a looser lepton selection, referred to as "loose" hereafter, and counts the numbers of observed events containing loose–loose, loose–tight, tight–loose and tight–tight lepton pairs. The probability of loose real leptons to pass the tight selection criteria is obtained using a $Z \to \ell^+\ell^-$ control sample, while the probability of loose fake leptons to pass the tight selection criteria is obtained using several control samples dominated by QCD jet events. Using these probabilities, linear equations can be obtained for the observed event counts as functions of the numbers of events containing fake–fake, fake–real, real–fake and real–real lepton pairs. These four equations can be solved simultaneously to yield the fake lepton background for the SS and OS analyses.

The contribution from the incorrect electron charge assignment background to the SS analysis is studied using $Z \to e^+e^-$ MC events by comparing the charges of generator level electrons to those of reconstructed electron candidates following the application of the SS analysis cuts. The background contribution is calculated as a function of the electron rapidity and applied to $t\bar{t} \to e^{\pm}\ell^{\mp}$ ($\ell = e, \mu$) MC events to obtain the $t\bar{t}$ contribution in the SS analysis. The method is validated with data by looking at the number of SS $Z \to e^{\pm}e^{\pm}$ events in a sample selected by requiring a lepton pair with invariant mass between 60 GeV and 120 GeV. The method predicts 61.3 ± 0.4 events compared with 62 observed events in the data.

The number of $t\bar{t}$ events in the OS signal region (SR) is obtained by multiplying the observed number of $t\bar{t}$ events in an appropriately defined control region (CR) by a factor $F(\mathrm{CR} \to \mathrm{SR})$, defined as the ratio between the number of $t\bar{t}$ MC events in the SR and the number of MC events in the CR. A $t\bar{t}$ dominated control region is defined by selecting "top-tagged" lepton pair events which satisfy the same selection criteria as signal candidates except for a $60 < E_{\mathrm{T}}^{\mathrm{miss}} < 80$ GeV requirement, defining a region in which both the Z contribution and the SUSY signal contamination are small. Events in this region are top-tagged using the variable m_{CT}, introduced in Ref. [34]. For two identical decays of heavy particles into two visible particles (or particle aggregates) v_1 and v_2, and into invisible particles, m_{CT} is defined as:

$$m_{\mathrm{CT}}^2(v_1, v_2) = \left[E_{\mathrm{T}}(v_1) + E_{\mathrm{T}}(v_2)\right]^2 - \left[\mathbf{p_T}(v_1) - \mathbf{p_T}(v_2)\right]^2, \tag{1}$$

where transverse momentum vectors are denoted by $\mathbf{p_T}$ and transverse energies E_{T} are defined as $E_{\mathrm{T}} = \sqrt{p_{\mathrm{T}}^2 + m^2}$. In (1) v_i can be a lepton, a jet, or a lepton-jet combination. The distributions of m_{CT} for each of these combinations, as well as the distributions of invariant mass for jet+lepton pairs generated in the same top quark decay, possess kinematic end-points which are functions of the masses of the top quark and W boson as detailed in Ref. [35]. An event is considered to be top-tagged if it includes two jets with $p_{\mathrm{T}} > 20$ GeV and the three m_{CT} variables and the lepton-jet invariant masses are compatible with the kinematics of fully leptonic $t\bar{t}$ ($t\bar{t} \to \ell^+\nu\ell^-\bar{\nu}b\bar{b}$) events. A total of 15 top-tagged data events are observed in the CR compared with a MC expectation of 21.3 ± 3.8 events, of which 18.8 arise from $t\bar{t}$ production and 2.5 from other SM sources. The quoted uncertainty is the statistical error on the MC samples. The estimated total number of $t\bar{t}$ events in the SR for the OS analysis is $2.9^{+1.4}_{-1.3}$. The quoted uncertainties include the statistical uncertainty on the number of events observed in the CR and the systematic uncertainty on the MC extrapolation to high $E_{\mathrm{T}}^{\mathrm{miss}}$. The latter arise from MC modelling of top quark production and decay (23%), and uncertainties in jet energy scale [36] and resolution [37] (23%). The sources of uncertainty in the Monte Carlo modelling considered were the choice of the NLO generator, the choice of the parton shower, and the modelling of initial and final state QCD radiation. The resulting total systematic uncertainty on the estimated number of $t\bar{t}$ events in the OS analysis is 44%. The predicted $t\bar{t}$ background contribution in the SR for the OS analysis, broken down into the three possible lepton flavour combinations, is given in Table 1.

A partially data-driven approach is adopted to estimate the contribution from Z production in the e^+e^- and $\mu^+\mu^-$ channels of the OS analysis. A control region is defined requiring $E_{\mathrm{T}}^{\mathrm{miss}} < 20$ GeV and $81 < m_{\ell\ell} < 101$ GeV, where non-Z contributions are found to be negligible. A normalisation factor between the CR and the SR is obtained from

Table 1 Total number of observed events in the SS and OS signal regions together with background expectations for an integrated luminosity of 35 pb^{-1}. The negative numbers for the fakes and the cosmics are an artefact of the matrix method and are taken as zero when calculating the total number of background events. The total error is a sum in quadrature of the statistical and systematic errors. The correlated systematic errors are combined linearly where as the uncorrelated systematic errors are summed in quadrature

	Same Sign, $E_{\mathrm{T}}^{\mathrm{miss}} > 100$ GeV		
	$e^{\pm}e^{\pm}$	$e^{\pm}\mu^{\pm}$	$\mu^{\pm}\mu^{\pm}$
Data	0	0	0
Fakes	0.12 ± 0.13	0.030 ± 0.026	0.014 ± 0.010
Di-bosons	0.015 ± 0.005	0.035 ± 0.012	0.021 ± 0.009
Charge-flip	0.019 ± 0.008	0.026 ± 0.011	–
Cosmics	–	$0^{+1.17}_{-0}$	–
Total	0.15 ± 0.13	$0.09^{+1.17}_{-0.03}$	0.04 ± 0.01
	Opposite Sign, $E_{\mathrm{T}}^{\mathrm{miss}} > 150$ GeV		
	$e^{+}e^{-}$	$e^{\pm}\mu^{\mp}$	$\mu^{+}\mu^{-}$
Data	1	4	4
$t\bar{t}$	$0.62^{+0.31}_{-0.28}$	$1.24^{+0.62}_{-0.56}$	$1.00^{+0.50}_{-0.45}$
Z+jets	0.19 ± 0.15	0.08 ± 0.08	0.14 ± 0.17
Fakes	-0.02 ± 0.02	-0.05 ± 0.04	–
Single top	0.03 ± 0.05	0.06 ± 0.08	0.10 ± 0.07
Di-bosons	0.09 ± 0.03	0.06 ± 0.03	0.15 ± 0.03
Cosmics	–	-0.2 ± 1.18	-0.43 ± 1.27
Total	$0.92^{+0.42}_{-0.40}$	$1.43^{+1.45}_{-0.59}$	$1.39^{+1.41}_{-0.53}$

this region using the MC. This factor is applied to the data in the CR in order to estimate the contributions to the signal regions. The $e\mu$ contribution is estimated solely using MC due to lack of events in the control region. The resulting numbers are presented in Table 1. The contributions from other SM processes such as single-top and di-boson production are estimated using MC samples and found to be small. The contribution of events from cosmic ray interactions is considered only for the $e\mu$ channels (arising from a single cosmic ray muon in coincidence with a collision electron) and the opposite-sign $\mu\mu$ channels (arising from a single cosmic ray muon traversing the detector which is reconstructed as two opposite-sign muons). This contribution is extracted from the number of selected muons which fail a tight cut on the minimum distance in the transverse plane of the associated inner detector track from the reconstructed primary vertex. The method requires knowledge of the probabilities for cosmic and collision muons to fail this cut. The former is measured from a dedicated data sample selected with a cosmic ray trigger, while the latter is extracted from simulation.

The observed numbers of events and the expected numbers of SM background events in the signal regions for the SS and OS analyses are shown in Table 1. The expected total number of SM events is 0.28 ± 0.14 for the SS analysis compared with zero events observed in the data, and 3.7 ± 1.6 for the OS analysis compared with nine events observed in the data. The $E_{\mathrm{T}}^{\mathrm{miss}}$ distributions measured with data for both analyses and the expectations from Monte Carlo simulation of Standard Model processes are shown in Fig. 1. For the SS channel the background expectations are found to be in agreement with the observation. All of the 9 selected OS events were visually scanned, and the highest $E_{\mathrm{T}}^{\mathrm{miss}}$ $\mu\mu$ event ($\sim$600 GeV, in overflow in Fig. 1) was found to be a likely candidate for a cosmic ray interaction in the detector. The number of observed events in the OS analysis is larger but in reasonable agreement with the background expectation. The channels with the most significant deviation are $e\mu$ and $\mu\mu$, for which the probabilities of the background to exceed the number of observed events are 12% and 13%, respectively. The combined probability of the ee, $e\mu$ and $\mu\mu$ channels is 12.8%.

Limits are set on the contributions to the considered final states from new physics, using a profile likelihood ratio method [38]. The likelihood function used to fit the event counts in the signal regions can be written as $L(n|s, b, \boldsymbol{\theta}) = P_S \times C_{\mathrm{syst}}$, where n represents the number of observed data events, s is the new physics signal to be tested, b is the background and $\boldsymbol{\theta}$ are nuisance parameters for the systematic uncertainties (such as jet and lepton energy scales and resolutions). In the profile likelihood approach, there is no truncation or integration over nuisance parameters. The nuisance parameters model the Gaussian sampling distribution of a control measurement for each of the systematic uncertainties [39]. These nuisance parameters are then profiled. P_S is the Poisson probability distribution for the event count in the signal region and C_{syst} represents the constraints on systematic uncertainties taking into account correlations. The limits are then derived from the profile likelihood ratio, $\Lambda(s) = -2(\ln L(n|s, \hat{\hat{b}}, \hat{\hat{\boldsymbol{\theta}}}) - \ln L(n|\hat{s}, \hat{b}, \hat{\boldsymbol{\theta}}))$, where $\hat{s}$, $\hat{b}$ and $\hat{\boldsymbol{\theta}}$ maximise the likelihood function and $\hat{\hat{b}}$ and $\hat{\hat{\boldsymbol{\theta}}}$ maximise the likelihood for a given choice of s. The signal strength is constrained to be positive. The test statistic is defined as $\Lambda(s)$ and exclusion p-values are obtained using pseudo-experiments. We apply the PCL procedure [40] whereby, if the observed (unconstrained) limit is found to be more than one standard deviation below its expected value under the background-only hypothesis, then the quoted limit is given as the expectation minus one standard deviation. In the present analysis, however, the observed limits fluctuated downward by less than 1 sigma (or, in some channels, fluctuated upward), and therefore the quoted limit is the same as would be found without the power constraint. The PCL procedure has been chosen for its better coverage properties compared to the CLs method [41, 42].

Using the observed numbers of data events and background expectations in the signal region, 95% confidence

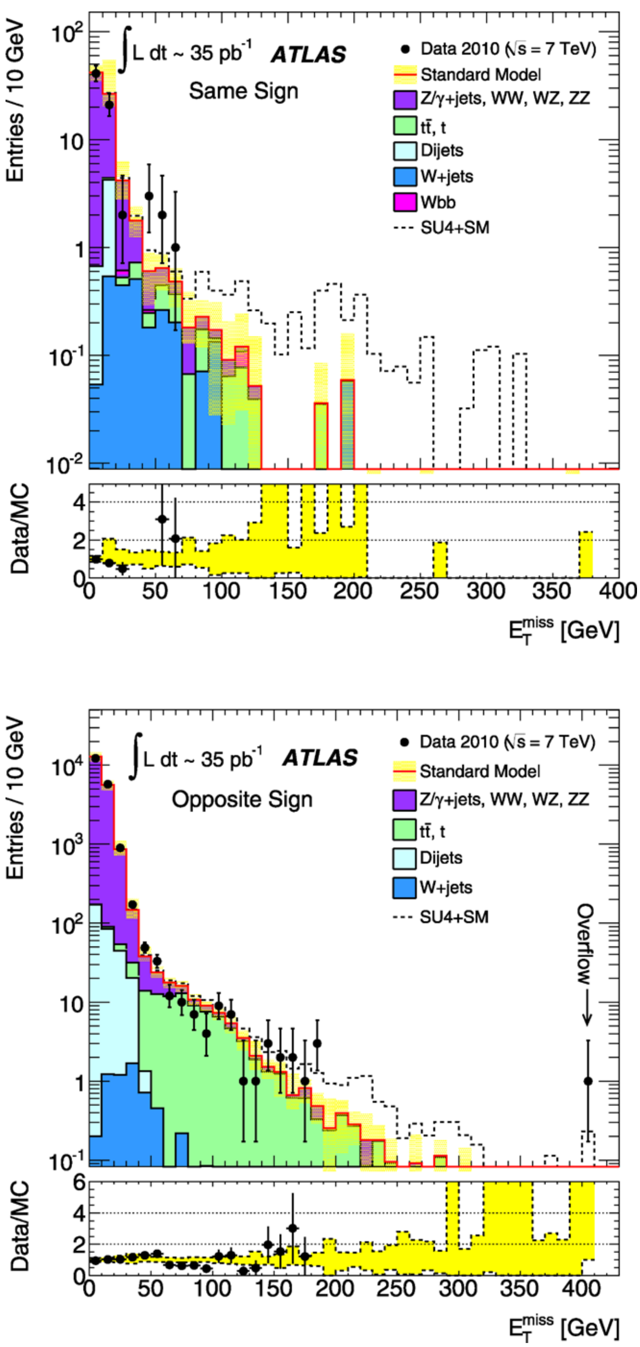

Fig. 1 (Color online) Distributions of $E_{\mathrm{T}}^{\mathrm{miss}}$ for SS (*upper*) and OS (*lower*) lepton pair events passing the analysis selections. The data are shown as *points* with *error bars* superimposed on the expected SM background distributions determined (mostly data-driven) with MC simulation. The overflow point in the OS $E_{\mathrm{T}}^{\mathrm{miss}}$ histogram is a likely candidate for cosmic ray interaction. In the *bottom panel* the ratio between the data and the total SM background is shown. The *histogram* labelled "Standard Model" represents the sum of all backgrounds and the light (*yellow*) bands indicate the uncertainty on the MC predictions from finite MC statistics and uncertainties in cross section, luminosity and jet and lepton energy scales and resolutions. "SU4" represents a point in the mSUGRA/CMSSM parameter space with $m_0 = 200$ GeV, $m_{1/2} = 160$ GeV, $A_0 = -400$ GeV, $\tan\beta = 10$ and $\mu > 0$

upper limits on the cross section times branching ratio times acceptance times efficiency are obtained for new physics processes producing lepton pairs and $E_{\mathrm{T}}^{\mathrm{miss}}$ of 0.07 pb (SS channels), 0.09 pb (e^+e^- channel), 0.21 pb ($\mu^+\mu^-$ channel) and 0.22 pb ($e^\pm\mu^\mp$ channel). These limits are better than those derived from simple Poisson statistics because of the introduction of continuous nuisance parameters which breaks the overcoverage stemming from Poisson discreteness. For the SS analysis the limits are calculated using the sum of the three different channels ee, $\mu\mu$ and $e\mu$. For the OS analysis limits are calculated for the three channels separately, and then combined statistically, as in SUSY models the signal resulting in OS same-flavour pairs may be different from the one generating different-flavour pairs. The combination is performed using a combined likelihood which is the product of the likelihoods from each of the OS dilepton channels.

Within the mSUGRA/CMSSM framework [43–48], these results are interpreted as limits in the $(m_0, m_{1/2})$ plane, for the $\tan\beta = 3$, $A_0 = 0$, $\mu > 0$ slice of the model. Model grids in a more general MSSM 24-parameter framework as defined in Ref. [53] are also studied. For these models (referred to as "MSSM PhenoGrid2" hereafter) the following parameters are fixed: $m_A = 1000$ GeV, $\mu = 1.5 \times \min(m_{\tilde{g}}, m_{\tilde{q}})$, $\tan\beta = 4$, $A_t = \mu/\tan\beta$, $A_b = \mu\tan\beta$, and $A_l = \mu\tan\beta$. The masses of third generation sfermions are set to 2 TeV, and common squark and slepton mass parameters are assumed for the first two generations. The remaining free parameters are the three gaugino masses and the squark and slepton masses. Two grids in the $(m_{\tilde{g}}, m_{\tilde{q}})$ plane are generated: one yielding soft final state kinematics, defined by $m_{\tilde{\chi}_2^0} = M - 50$ GeV, $m_{\tilde{\chi}_1^0} = M - 150$ GeV and $m_{\tilde{l}_L} = M - 100$ GeV, where M is the minimum of the gluino and squark mass ("compressed spectrum" models); and one with a very light LSP, yielding a harder spectrum of leptons, jets and $E_{\mathrm{T}}^{\mathrm{miss}}$, with $m_{\tilde{\chi}_2^0} = M - 100$ GeV, $m_{\tilde{\chi}_1^0} = 100$ GeV and $m_{\tilde{l}_L} = M/2$ GeV ("light neutralino" models). SUSY signal events are generated with HERWIG++ [54] for the mSUGRA/CMSSM models and with HERWIG for the MSSM models. Cross sections are calculated at NLO with PROSPINO [55]. Theoretical and experimental uncertainties on the signal rate are calculated for each model. Theoretical uncertainties are evaluated by varying the factorisation and renormalisation scales and by varying the CTEQ6.6 PDF sets [56] used for the cross section calculation. Experimental uncertainties include those due to the lepton and jet energy scale and resolution and an 11% uncertainty on the luminosity measurement are considered for both signal and background in the limit computation. The total uncertainty varies between 20% and 30% for most of the signal models considered in this analysis.

The expected and observed limits in the $(m_0, m_{1/2})$ mSUGRA/CMSSM plane are shown in Fig. 2 for both the

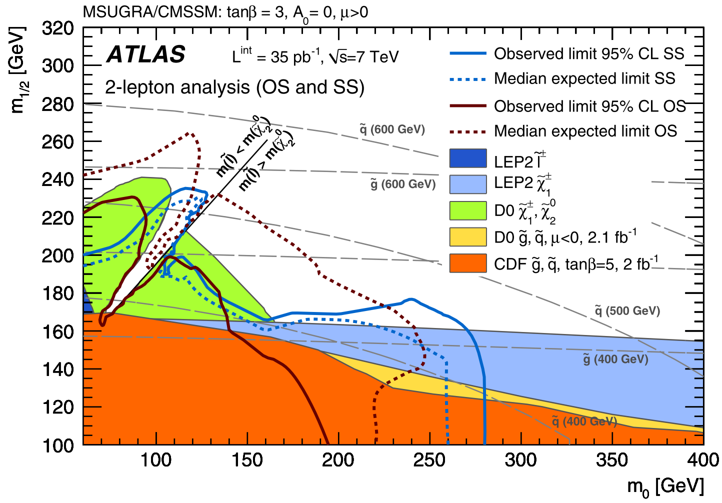

Fig. 2 (Color online) Exclusion in the mSUGRA/CMSSM [43–48] $(m_0, m_{1/2})$ plane for $\tan\beta = 3$, $A_0 = 0$ and $\mu > 0$, together with existing limits [49–52]. The expected (*dashed line*) and observed (*full line*) 95% C.L. exclusion limits are shown for the opposite-sign (*black line*) and same-sign (*blue line*) analyses. The illustrated D0 limit assumes $\mu < 0$

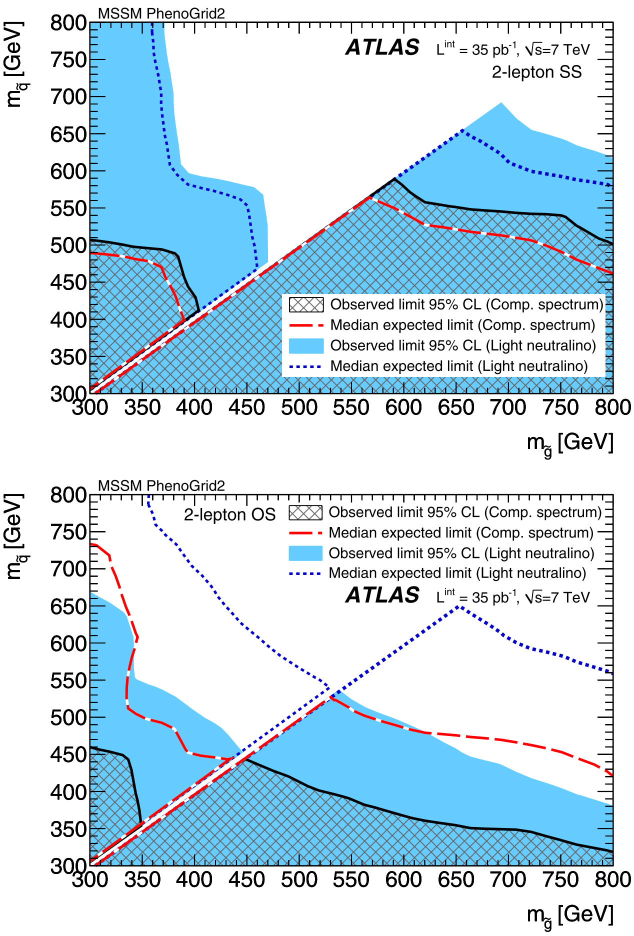

Fig. 3 Expected and observed 95% C.L. exclusion limits in the $(m_{\tilde{g}}, m_{\tilde{q}})$ plane for the specific MSSM models described in the text. The *upper panel* is for the SS analysis, the *lower panel* for the OS analysis

OS and SS analyses. The excluded region of parameter space is similar to that excluded by the Tevatron experiments based on the study of trilepton final states [51], and exceeds the Tevatron squark and gluino mass limits from signatures including jets and $E_{\mathrm{T}}^{\mathrm{miss}}$ [49, 50]. For the MSSM grids the results are shown in the $(m_{\tilde{g}}, m_{\tilde{q}})$ plane in Fig. 3 for the SS analysis (upper panel) and OS analysis (lower panel). For the considered models and $m_{\tilde{g}} = m_{\tilde{q}} + 10$ GeV, the lower limits on the squark mass for the "compressed spectrum" ("light neutralino") scenarios are 450 (550) GeV and 590 (690) GeV for the OS and SS analysis, respectively. The achieved limits extend the region of squark and gluino mass explored with direct searches based on jets and $E_{\mathrm{T}}^{\mathrm{miss}}$ by previous experiments.

In conclusion, a search for the production of SUSY particles giving rise to final state with a pair of leptons and large $E_{\mathrm{T}}^{\mathrm{miss}}$ has been carried out using 35 pb^{-1} of data collected by the ATLAS experiment at the LHC in 2010. Two analyses have been performed, using, respectively, same-sign and opposite-sign lepton pair signatures. The observed numbers of events in the signal regions of both analyses are compatible with SM expectations. These results have been interpreted as limits in the parameter spaces of three different SUSY models, namely the mSUGRA/CMSSM framework, and two classes of MSSM models with a compressed SUSY particle mass spectrum and with a light neutralino. Depending on model assumptions squarks with masses between 450 and 690 GeV are excluded, for squarks approximately mass degenerate and lighter than gluinos, extending the coverage of previous experiments.

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